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Original Research Paper

The optimum conditions for solid-state-prepared $(Y_{3-x}Ce_x)Al_5O_{12}$ phosphor using the Taguchi method

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ABSTRACT

Using the Taguchi method, the authors analyzed the optimum conditions for $(Y_{3-x}Ce_x)Al_5O_{12}$ (YAG:Ce) phosphor, which is prepared using the solid-state reaction method. The controllable factors used in this study consisted of the following: (1) the duration of milling, (2) the quantity of substitution, (3) the duration of sintering, and (4) the temperature of sintering. Under optimum conditions, a confirmation experiment was carried out, and the average photoluminescence (PL) intensity of YAG:Ce phosphor was found to be up to 270.84 (a.u.). The percentage contribution of each controllable factor was also determined. Most interestingly, the temperature of sintering is the most influential factor within current investigation range to the solid-state-prepared YAG:Ce phosphor, and its value of percentage contribution is up to 70.90%. Aside from this, through the optimum conditions, the average PL intensity of YAG:Ce phosphor can be substantially promoted from 193.88 (a.u.), the average PL intensity of YAG:Ce phosphor sintered at 1500 °C for 6 h that was usually used to sinter YAG:Ce phosphor.

1. Introduction

With increasing concerns about energy demands and the global warming, the development of energy-saving productions, such as white light-emitting diode (WLED), has received substantial attention. The combination of a blue light-emitting diode (LED) with the yellow phosphor is one of the promising methods of generating the white light. Consequently, trivalent cerium (Ce^{3+}) activated yttrium aluminum garnet $Y_3Al_5O_{12}$ (YAG) phosphor has attracted substantial interest because the YAG:Ce phosphor can effectively convert the blue light emitted by InGaN/GaN LED chips into a very broad band of yellow emission that provides a basis to produce WLED [1–4].

The YAG:Ce (or YAG) phosphor is usually synthesized by various methods such as solid-state reaction [1,3–8], combustion [1,2,5,9–12], sol–gel [1,3,13–17], sol–gel combustion [18,19], co-precipitation [1,20–25], polyacrylamide gel method [26], and solvothermal method [27]. Even though the solid-state reaction needs a high sintering temperature and a long reaction duration to synthesize the YAG:Ce phosphor, it is commonly used in the large-scale production of phosphor. This is attributed to the fact that a better luminous intensity can be obtained through the solid-state reaction [19].

The optimum conditions of the solid-state-prepared YAG:Ce phosphor are seldom studied using the Taguchi method [28]. This fact is the main motivation for this investigation. Moreover, an attempt to study the percentage contribution of each experimental parameter to the solid-state reaction process has seldom been undertaken. Therefore, in this study, the duration of milling, the quantity of substitution, the duration of sintering, and the temperature of sintering were used as the controllable factors. The optimum conditions for preparing YAG:Ce phosphor with better luminous intensity and the percentage contribution of each aforementioned experimental parameter to the process were determined using the Taguchi method [28]. Fig. 1 presents the research procedure done in this study.

2. Taguchi method

The Taguchi method [28] has been adopted to optimize the design parameters [29–36] because this systematic approach can significantly minimize the overall testing time and the experimental costs. The optimum experimental conditions can easily be determined using the orthogonal array specially designed for the Taguchi method. This study considers four controllable factors,

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